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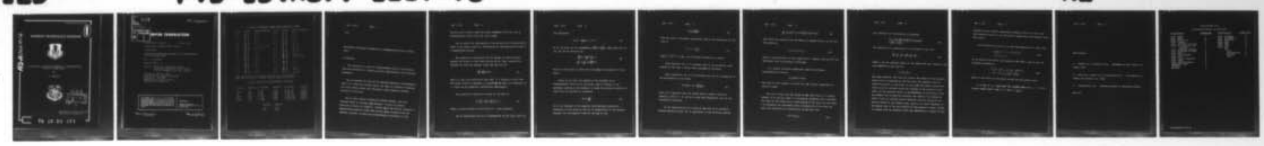

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FOREIGN TECHNOLOGY DIVISION

CALCULATING NONLINEAR MOVEMENTS OF INCOMPRESSIBLE
FLUID IN INNER SHELL

By

A. Mayrykov

EDITED TRANSLATION

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; *e* elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	sinh^{-1}
cos	cos	ch	cosh	arc ch	cosh^{-1}
tg	tan	th	tanh	arc th	tanh^{-1}
ctg	cot	cth	coth	arc cth	coth^{-1}
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

1117

Calculating Nonlinear Movements of Incompressible Fluid in Inner Shell

A. Mayrykov

The problem of a flow of incompressible fluid is interesting from the standpoint of studying certain physiological and technical processes.

Let us examine the flow of an ideally conductive incompressible fluid in a tube with elastic walls. The tube is capable of changing its cross section under the influence of the internal pressure exerted by the fluid.

Let us take coaxial cylindrical shells (tubes). Here the internal shell is elastic, the external - rigid. An azimuth electrical current of force J, travels along the shells, creating a longitudinal magnetic field. The current which travels along the internal cylinder is equal and proportional in direction to the

current which travels along the outer cylinder. Here the flow of incompressible fluid fills the inner tube.

Let us reduce our description of the motion of an incompressible fluid in an elastic tube to a description of one-dimensional flows of a compressible medium.

The equation of continuity for the volume of fluid included between the planes of the cross section of the tube, separated by distance dx from one another, takes the form of [1]:

$$\frac{\partial S}{\partial t} + \frac{\partial}{\partial x}(SV) = 0. \tag{1}$$

Here s is the cross section of the tube, V - velocity of the flow. The radial velocity component is assumed to be small in comparison to V_x, since we are examining longitudinal wavelengths.

The equation of motion is written in the form of

$$\rho S\left(\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x}\right) + \frac{\partial}{\partial x}(P^{*}S) = 0. \tag{2}$$

where ρ is the density of the fluid, P* - total pressure.

Let us approximate the law of deformation of the inner shell by

the expression:

$$p = AS^{\gamma} \quad \text{where} \quad A\text{-const.} \tag{3}$$

If we use from [2] the expression $\frac{1}{\rho S}\frac{\partial(p^{*}S)}{\partial x} = a^{2}\frac{\partial \ln S}{\partial x}$, then equations (1) and (2) can be rewritten as

$$\frac{\partial \ln S}{\partial t} + v\frac{\partial \ln S}{\partial x} + \frac{\partial v}{\partial x} = 0. \tag{4}$$
$$\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial x} + a^{2}\frac{\partial \ln S}{\partial x} = 0.$$

Here a is the speed at which the disturbance is propagated in the fluid.

Thus, we see that the problem of the movement of an incompressible fluid can in the given case be reduced to the analogous problem of gas dynamics in which the standard equation of state will be replaced by expression

$$p^{*} = p + \frac{H^{2}}{8\pi} \tag{5}$$

(H is the strength of the magnetic field between cylindrical surfaces). On the basis of the law of preservation of the magnetic current, for the magnetic field in the gap we get:

$$H = H_0 \frac{S' - S_0}{S' - S}. \tag{6}$$

With the latter considered, expression (5) can be represented in the form of

$$P^* = AS^{\gamma} + \frac{B}{(S' - S)^2}. \tag{7}$$

where $B = \frac{2\pi I^2}{c^2}(S' - S_0)^2$ and c is the speed of light in a vacuum.

From expresson (7) it is apparent that as the pulsating cross section of the tube S grows, total pressure P* increases.

Using expression (7) we can determine the rate of propagation of the disturbance in the fluid:

$$a^2 = \frac{1}{\rho}\left[A(\gamma + 1)S^{\gamma} + \frac{B(S' + S)}{(S' - S)^3}\right]. \tag{8}$$

Hence it is apparent that the second term is always a positive quantity, since S' > S, and as S grows the propagation rate of the disturbance increases.

It was demonstrated in [3] that in the case of an adiabatic process equation system (4) is equivalent to the following system:

$$\frac{\partial}{\partial t}(v \pm \int a\, d\ln S) + (v \pm a)\frac{\partial}{\partial x}(v \pm \int a\, d\ln S) = 0 \tag{9}$$

Now, using the apparatus of the theory of Riemann waves, let us find the solutions

$$x = (v \pm a)t + F(v), \tag{10}$$

which is characteristic in the plane (v, a). Unknown function $F(v)$ is determined from the boundary conditions.

In a simple traveling compression wave the following relationship is correct:

$$v = \int a\, d\ln S + const$$

The value of the constant is found from the initial conditions in specific cases.

Now let us also plot the analog of the shock wave in a coaxial system. If we use the index I to designate parameters which describe the state of the medium up to intersection of the break and the index 2 to designate the parameters after intersection of the break and write the condition for conservation of the mass flow

$$u_1 S_1 = u_2 S_2 = j, \tag{12}$$

the condition for conservation of momentum

$$P_1 S_1 + \rho S_1 u_1^2 + \frac{H_0^2}{8\pi} S_1 \left(\frac{S'-S_0}{S'-S_1}\right)^2 = P_2 S_2 + \rho S_2 u_2^2 + \frac{H_0^2}{8\pi} S_2 \left(\frac{S'-S_0}{S'-S_2}\right)^2, \quad (13)$$

the condition for conservation of the energy of the flow

$$\frac{u_1^2}{2} + \frac{\varepsilon_1}{\rho} + \frac{P_1}{\rho} = \frac{u_2^2}{2} + \frac{\varepsilon_2}{\rho} + \frac{P_2}{\rho}, \quad (14)$$

where ε_i is the internal energy of the system per unit folume in the cross section of the tube Si:

$$\varepsilon = \frac{1}{se}\int \rho dV.$$

Note that equation (14) does not contain the energy of the magnetic field. This is explained by the fact that the magnetic field is directed parallel to the flow. In this case the induced electrical vortex field is directed along the tangent to the surface of the tube, and the Poynting vector is perpendicular to the walls in the gap between the cylindrical surfaces. The energy of the magnetic field in the gap changes and is converted into the potential and kinetic energy of the system. Thus, there is no axial component in the energy flux in the gap occupied by the magnetic current. Energy is removed from the magnetic field and converted as a result of the

presence of the central compressible shell filled with fluid. The Umov-Poynting vector of the flow-shell system also runs parallel from this shell.

From conditions (12)-(14) we find the expression for mass flow:

$$j = \frac{S_1 S_2}{\rho(S_2 - S_1)}\left[P_2 S_2 - P_1 S_1 + \frac{H_0^2}{8\pi} S_2\left(\frac{S' - S_0}{S' - S_2}\right)^2 - \frac{H_0^2}{8\pi} S_1\left(\frac{S' - S_0}{S' - S_0}\right)^2\right]. \qquad (15)$$

If we exclude velocities from equations (12)-(14), then we get the following expression:

$$P_2 S_2\left[S_2 - \frac{\gamma+3}{\gamma+1} S_1\right] = P_1 S_1\left[S_1 - \frac{\gamma+3}{\gamma+1} S_2\right] - \frac{H_0^2}{8\pi}(S' - S_0)^2 (S_1 + S_2)\left[\frac{S_2}{(S' - S_1)^2} - \frac{S_1}{(S' - S_2)^2}\right], \qquad (16)$$

which is the analog of the shock adiabat in the studied case.

If we set $\frac{P_1}{P_2} \to 0$, then from (16) we find that when $\gamma = 1$ on the "intense shock wave" front $S_2 = 2S_1$ and $H_2 = H_1 \frac{S' - S_1}{S' - 2S_1}$.

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